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University of Kentucky

TOBACCO DISEASES

BULLETIN NO. 362

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RECOMMENDATIONS FOR CONTROL OF TOBACCO DISEASES IN KENTUCKY

Seed. Obtain seed of a satisfactory black-root-rot-resistant strain of tobacco, if possible, and plant no other kind until a better variety has been found. Two-year-old seed is preferable to one-year-old, for it is more likely to be free from the leaf-spot bacteria. Seed should not be saved from plants affected with ring-spot. Chemical treatment of seed probably is beneficial.

Plant Beds. Select a plant-bed site each year where tobacco has not been grown previously. A bed used year after year becomes infested with the black root-rot fungus unless burned or steamed thoroly or a highly resistant strain of tobacco has been grown. Beds should be located away from tobacco barns or other sources of tobacco trash. Burn or steam the bed very thoroly so that little weeding will be necessary. If horsenettles or groundcherries are found in the bed it is best not to handle them at all, either while weeding or pulling, because they sometimes carry mosaic. Never use ground tobacco stalks or other tobacco material, as it comes from the barn, on the bed as a fertilizer, because it is nearly certain to introduce mosaic. Commercial fertilizers are safe and are as effective as tobacco materials.* Boil old tobacco cotton unless it has been stored in a place free from tobacco trash. Have the cotton as insect-proof as possible as there is a chance of the introduction of disease by insects. Experience has shown that tightly boxed and covered beds are more likely to be free from wildfire and angular leaf-spot than unboxed beds. When the tobacco plants are established in the bed, that is, when the first leaves are just developing, spray or sprinkle the bed with 3-4-50 Bordeaux mixture at the rate of 1 quart per square yard. This tends to prevent the bacterial diseases, angular leaf-spot and wildfire.

Chewing and Smoking While Handling Plants. It has been clearly demonstrated in Kentucky that cured tobacco is the source of most of the mosaic infection of tobacco plants before and during transplanting. Therefore do not use natural leaf tobacco for either chewing or smoking and do not carry it or otherwise handle it while working around the plant bed. If natural leaf tobacco has been handled recently, scrub the hands thoroly with soap and water before handling plants in the bed. If natural leaf tobacco has been carried in the pockets, brush them out, after which plug or twist tobacco may be substituted. Commercial plug, twist, and scrap chewing tobacco usually are free from mosaic and are much safer to use than natural

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* See pages 9 and 10, Kentucky Extension Circular 77 (revised), for plantbed fertilizers.

leaf tobacco. Pipe smokers should use a brand of canned smoking tobacco rather than the natural leaf. Manufactured cigarettes probably are safe to use while working with the plants. It is preferable, however, to use no tobacco whatever when working in the bed.

Field Practices. Do not set plants from a bed known to be affected with black root-rot unless the field soil is known to be distinctly acid. Soil high in organic matter, liberal applications of high-grade fertilizer, and liberal applications of manure all tend to reduce blackfire. The few mosaic plants found at the first cultivation or at any time when the plants are small should be removed. If this is done by hand, healthy plants should not be touched until the hands have been washed with soap and water. If mosaic plants are encountered in Burley fields at topping time, they may be left untouched until cutting time, or topping may be delayed until most of the plants are in bloom, when all may be topped together without injury to the crop. Mosaic causes more injury to dark tobacco when spread at topping time than to Burley because dark tobacco is topped earlier than Burley. Consequently, efforts should be made to have the field free from mosaic at topping time. If mosaic plants are found they should be passed without touching and topped last. In wet seasons, when leafspot of Burley tobacco is likely to be severe after topping, the last suckering should be delayed until cutting time and the tobacco cut immediately after suckering.

Horn-worms should be controlled by dusting rather than by hand worming. Handling the plants may spread mosaic, especially when wet.

Curing. To produce well-cured leaf and to prevent houseburn, keep the relative humidity at about 80 to 85 percent until the leaves are dead and then gradually reduce it to 65 percent. Relative humidity above 90 percent is almost sure to cause houseburn if the tobacco is exposed to it for as long as twenty-four hours, especially at the higher temperatures within the range of curing. Burley tobacco is darkened when it comes in high case after it is cured.

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TOBACCO DISEASES

W. D. VALLEAU and E. M. JOHNSON

It should be the object of every tobacco grower to reduce the chances of crop failure to the greatest extent possible. There are numerous diseases of tobacco some of which may be prevented completely by proper management of the crop. It is recognized that it is not always an easy matter for the grower to become familiar with the details of each of the numerous diseases with which a crop may be affected, and with the methods of prevention recommended for each. For this reason a summary of recommendations for disease control has been prepared (see pages 5 and 6) which, if closely followed, should be effective against diseases for which control methods are known, without requiring a detailed knowledge of any one of them. A more extensive discussion of the diseases, together with illustrations, is presented for those who are interested in a detailed study.

CAUSES OF TOBACCO DISEASES

Tobacco diseases may be considered as abnormalities of the plant which cause reduced quality or quantity of the commercial product. This definition includes malnutrition diseases of various types caused by soil deficiencies, injuries caused by fungi, bacteria, round worms or nematodes, parasitic flowering plants as broomrape, virus diseases, and injury caused by burning of wilted plants. Insect injuries might be included, but are not discussed in this Bulletin. If it is kept in mind that diseases may be produced by one or a combination of these causes, it will be easier to understand the reasons for the various control measures recommended and the changes which are made from

time to time in these recommendations as new facts are discovered. A short description of the organisms that cause disease may be of interest to those unacquainted with the lower forms of life.

Fungi are plants of a low order represented by mushrooms or toadstools and various molds which grow in damp places. A common fungus familiar to all is the green mold often seen on canned fruit. Certain forms of fungi are common causes of plant disease. They subsist either on the living plant cells, as rust of wheat and other cereals, and mildews of various crops, or by killing the plant cells and living on the dead tissues, as in fruit rots or black root-rot of tobacco.

Bacteria are sometimes classed as one of the groups of fungi. They are single-celled plants. The individual cells are visible only with a microscope. A mass of them, however, is readily visible to the unaided eye.

Virus diseases are caused by substances which differ from known living organisms. The individual particles are too small to be seen with a microscope but can be removed with sufficiently fine filters. The virus content of the plant increases rapidly following infection but whether by multiplication or by chemical reactions brought about by the presence of virus particles is not known.

Nematodes are round worms which can sometimes be seen with the unaided eye. They are similar to the hookworm of the human and to round worms causing troubles in many animals.

Parasitic flowering plants are plants such as broomrape, dodder, and mistletoe which have become adapted to obtaining food materials or nutrients directly from some other living plant instead of from the soil.

Physiological diseases, or those not caused by disease-producing organisms, often result from a lack of sufficient available nutrients or an excess of one or more of the compounds necessary for plant growth. The quantity of available nutrients in the soil may be influenced by changing soil conditions, such as

temperature and moisture, as well as by the total quantity present.

SOIL IN RELATION TO TOBACCO DISEASES

Growers are well aware of the desirability of selecting the most favorable soil for tobacco. The reasons for the selection or rejection of certain soils for tobacco are not always well understood but are usually arrived at by experience. The relation of soil to diseases will be discussed more fully under the specific diseases but reference is made here to a few of the more obvious relations.

Soil Fertility. A proper balance of the necessary nutrients must be maintained in the soil thruout the growth period of the tobacco plant, to obtain normal development. Lack of sufficient quantities of certain compounds may cause leaf spots and various other types of deficiency or malnutrition diseases, or slow growth and late maturity of the crop.

Soil Reaction. Soil reaction or the degree of its acidity or alkalinity appears to be an important factor. Experience has demonstrated that tobacco thrives best in moderately acid soil. The use of too much lime tends to increase black root-rot and quite often seems to be a contributing cause of frenching. In strongly acid soil toxic materials are liberated which, when taken into the plant, cause slow growth and leaf spotting. On such soil a light application of lime may prove beneficial to tobacco.*

Organic Matter. Organic matter, if well rotted and mixed with the soil, is generally beneficial to tobacco because it tends to increase fertility and to reduce leaf-spot diseases. Manure is generally beneficial to both White Burley and dark tobacco, but if successive crops of tobacco are grown in manured soil, black root-rot is almost certain to develop. Plant debris, such as leaf mould, when turned under in newly cleared land, sometimes causes tobacco to french if it is the first crop.

* For recommendations on fertilizing soil for tobacco outside the Bluegrass, see Kentucky Experiment Station Bulletin 322, pages 414 to 416, and for recommendations on liming see pages 411 and 412. If the land is in the Bluegrass, see Bulletin 331, pages 262-264.

Crop Rotation. The tobacco grower should profit by past experience and give careful study to the selection of the crop which is to precede tobacco in a rotation. Tobacco often grows slowly after corn, soybeans, alfalfa or timothy; whereas the crop appears to benefit if it follows red clover, bluegrass, orchard grass, lespedeza or a heavy stand of weeds. A large amount of organic matter such as a heavy sod or weed growth turned under usually is beneficial to tobacco. However, where heavily pastured sods are turned under, tobacco not properly fertilized often grows slowly and makes leaf of poor quality.

Physical Condition of Soil. Good physical condition of the soil is necessary, especially good surface and under drainage. Tobacco often frenches on soil which is too wet, or if water stands long about the plants it may cause them to wilt, turn yellow, and finally die. On hard, poorly aerated soil tobacco grows slowly and produces inferior leaf. Loose, open soil is likely to cause rapid-growing, high-quality tobacco, if the necessary nutrients are available.

PHYSIOLOGICAL DISEASES

Physiological diseases may be caused by a temporary or permanent lack of certain elements in the soil. Nitrogen, phosphorus and potassium are the three elements most likely to be deficient in Kentucky soils. Magnesium deficiency, which causes sand drown, and calcium deficiency, which causes irregularly shaped leaves, rarely, if ever, occur. The object of tobacco growing is to mature large, well-formed leaves of high quality. Such development largely depends on the proper nourishment of the plant. Therefore much attention should be paid to soil improvement and to the kind and amount of fertilizer used.

Nitrogen Deficiency. A deficiency of nitrogen is indicated by slow-growing, light-green plants. Yellowing of the lower leaves during dry periods often is caused by the inability of plants to obtain nitrogen and is a common example of nitrogen starvation. An abundance of available nitrogen in the soil, if other necessary elements and moisture are present, produces

rapid-growing, vigorous, dark-green plants, except in periods of excessive heat, when the lower leaves may yellow.

Prevention. Liberal applications of manure or of fertilizer high in nitrogen prevent nitrogen starvation.

Phosphorus Deficiency. This is indicated by slow-growing, stunted, dark green plants. This condition cannot be recognized readily unless plants well supplied with phosphorus and sufficient lime are growing nearby for comparison. A lack of available phosphorus appears to be a common cause of slow growth and late maturity of tobacco in most parts of Kentucky, outside of the Central Bluegrass area. In the greenhouse phosphorus-starved plants frequently develop water-soaked areas in the leaves, but it is not known what part the deficiency may play in the production of leaf-spots in the field and after the tobacco is harvested.

Prevention. Phosphorus starvation is prevented by the use of phosphate fertilizers or liberal applications of mixed fertilizers high in phosphorus. Manure is low in phosphorus and cannot be relied upon to correct phosphorus deficiency.

Potash Deficiency. Altho Kentucky soils generally are quite high in potash, tobacco frequently shows signs of potash starvation. This is because the rate at which potash becomes available in the soil is not great enough to meet the needs of the tobacco crop, which requires a large amount in a short time. Potash starvation is readily recognized in tobacco. A mild deficiency causes bronze yellow blotches on the leaves. In more severe cases the leaves are curled downward at the edges or are "rimbound". The portions of the blade of the leaf between the larger veins are curved upward as if the veins were too short. The leaf usually is light green with yellowish blotches, and the whole plant may have a distinct bronze tinge.

Prevention. Potash starvation may be prevented by applying barnyard manure, potash fertilizers, or liberal quantities of mixed fertilizers which contain a high percentage of potash. In sandy soils of the southeastern part of the United States too large an application of potassium chloride (muriate of potash)

Figure 1. A. Uncured leaf of white Burley tobacco. The chlorotic tip closely resembles sulfur deficiency. A small bit of leaf from a normal green leaf is shown for comparison. B. Two chlorotic leaves and a normal leaf (center) when nearly cured. The mid and lateral veins of the chlorotic leaves were still partly alive. The areas that were chlorotic before curing show clearly in the cured leaf.

causes tobacco leaves to thicken and curl upward. Cured tobacco containing too much chlorine is of inferior quality, as it holds water and consequently burns poorly. This difficulty has not been encountered in Kentucky except where excessive quantities of potassium chloride have been used experimentally. Seventy-five pounds per acre of potassium chloride probably can be used with safety anywhere in Kentucky.

Sulfur Deficiency. A condition sometimes occurs on the tips of ripening leaves of White Burley tobacco which is thought to be caused by insufficient sulfur. The affected leaves are green at the base but the tips are grayish yellow, the yellowing sometimes extends well down the edges of the leaves. Affected leaves yellow and dry out slowly after cutting. When cured the tip of an affected leaf is honey yellow and the remainder is brown (figure 1).

Prevention. Sulfur deficiency occurs where the surface soil has been removed by erosion and the land is left hard and impervious to rain. Tobacco growing on unfertilized land obtains a large part of its sulfur in the rainfall. A long dry period followed by heavy washing rain and rapid growth is believed to induce symptoms of sulfur deficiency. There is probably no reason for attempting to prevent the condition in White Burley tobacco in Kentucky. Sulfur-containing fertilizers such as superphosphate and sulfate of potash should be effective in overcoming sulfur deficiency.

Frenching. Frenching, or wet-weather french, tho sometimes confused with mosaic of tobacco, is a distinct disease. Newly frenched plants are nearly white in the growing point (figure 2). The frenched leaves are narrowed and drawn and the tips sometimes bend sharply downward forming a cup of the underside of the leaf. Later, affected leaves may turn dark green. In severe cases the leaves may be reduced to narrow straps made up mostly of the midvein, and the number of leaves is greatly increased, sometimes to hundreds on a plant. Frenching develops under a variety of conditions. It is more prevalent in seasons of abundant rainfall and nearly absent during pro-

tracted dry periods. Frequently it develops in plants in rich soil with an abundant water supply. If the soil moisture content is reduced before numerous lateral buds start growth, the plants may recover completely.

Figure 2. Frenching of White Burley tobacco which developed soon after the plant was set.

It may occur in soil that has been limed, whereas plants growing in similarly treated but unlimed soil, may be free from it. It appears that liming is more likely to induce frenching in soil of low rather than of high organic matter content. Liming does not always induce frenching during the period of growth

of the plant, even in an abnormally wet season, but it has frequently been observed that the suckers on otherwise healthy plants french and that the suckers which develop from the stubble, following harvest, french. This indicates that the soil is potentially a frenching soil but that sufficient nutrients were available to produce an apparently healthy crop. In the greenhouse tobacco plants eventually french in limed soil unless adequate nutrients are added.

Frenching occurs in soil which is near the neutral point (about pH 6 or above*) but it is probable that plants growing in soil of the most desirable acidity for tobacco (about pH 5.6) will not french. Studies of the disease in the greenhouse have shown that frenching sometimes is associated with a lack of available nitrogen in the soil, but at other times it seems to occur in the presence of available nitrogen when other nutrients as phosphorus are deficient.

The cause of frenching has not been determined, but it appears to be associated with slightly acid, neutral, or slightly alkaline soil. The numerous experiments which have been made to determine the cause seem to indicate that the immediate cause of frenching is within the plant itself. Studies at Duke University have shown that the pH of frenched plants is higher (more nearly neutral) than that of normal plants. An abnormally high pH could well affect the rate of translocation of the various compounds prepared in normal leaves to be transported to the newly unfolding leaves. Frenched growth is made up largely of cell walls (carbohydrates), with an inadequate proportion of the cell contents necessary for proper functioning of the cell (largely nitrogenous compounds). It is probable that soil conditions which cause a reduced hydrogen ion concentration within the plant, bring about, because of the change in pH, greater difficulty in translocation of nitrogenous organic compounds, unless the level of these within the plant is high.

* The term pH refers to acidity or alkalinity of the soil. A neutral soil has a pH of 7. Figures smaller than 7 indicate degrees of acidity; figures larger than 7, degrees of alkalinity. The soils of the Bluegrass Region are about pH 5.6 except in the hilly area where alfalfa can be grown without liming, where the pH is about 7. The soils of the rest of the State are slightly more acid.

As a consequence, a type of growth develops which is largely framework (carbohydrate) without the necessary furnishings (nitrogen compounds). Chemical analyses of frenched and normal plants seem to support this view.

Prevention. Frenching can always be prevented in the greenhouse by sufficient applications of the necessary fertilizing elements. Under field conditions prevention is not so simple because of the variety of conditions under which the disease occurs. The addition of readily decayable organic matter, proper soil drainage, and the application of fertilizers recommended for tobacco, probably will be beneficial in soil known to produce the disease. The addition of sulfur to frenched soil, in order to increase acidity, entirely prevented frenching in certain soils in North Carolina. Sulfur should be used in small amount until its effect on a given soil has been determined. Ammonium sulfate might be expected to be beneficial if used as one of the sources of nitrogen. If lime is to be used on tobacco land apply a small quantity following the tobacco crop rather than immediately preceding it.

PLANT-BED DISEASES

Under this heading only those diseases that are confined to the plant bed are discussed. Angular leaf-spot, wildfire, mosaic, and black root-rot all affect plants in the bed but will be discussed under their respective headings.*

Blackleg. This disease occurs in the plant bed during wet periods when the plants are about ready to be set. It is a bacterial soft rot attacking the leaves which touch the ground and spreading from them into the soft, tender stalk. This may rot off completely or, if the stalk has become somewhat hard, the rot may spread up one side, splitting it open. The rotted areas usually turn black, hence the name (figure 3). Frequently all

* Since this bulletin was written, downy mildew or blue mold caused by the fungus *Peronospora tabacina*, has been discovered in Todd County, Ky. It did not appear until about the first week in June, and then only in shaded parts of beds located in the woods. The disease causes large, brown spots on the leaves and is very destructive when introduced into the bed when the plants are growing rapidly. As it appears to carry over in plant beds infected the previous year, the same bed site should not be used again in areas where the disease is known to occur. It is probable that the outbreak in Kentucky was caused by spores blown in from the southeast.

the plants in a circle a foot to three feet in diameter are destroyed. Slightly affected plants when set in the field grow normally, but if kept over night for setting the following day

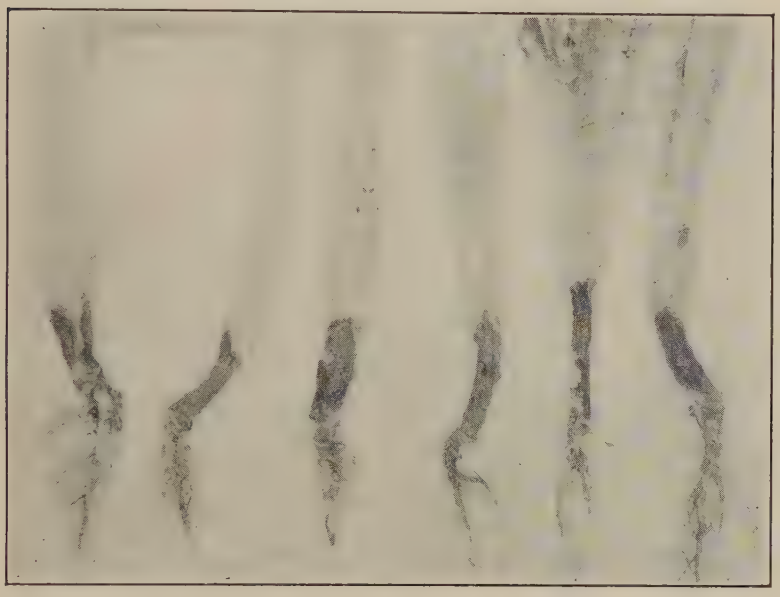

Figure 3. Blackleg of White Burley tobacco. The disease occurs in the plant bed as a soft rot, when the plants are about ready to set.

all the plants may be a slimy rotten mass. The disease is caused by *Bacillus aroideae,* one of the group of soft-rot bacteria which have been shown to be carried by certain insects. The method of entrance into the bed is not known, but it may be on trash sowed with seed (see discussion of stalk rot). Measures for prevention cannot be recommended other than that of removing the canvas and drying and hardening the plants when the disease is first noticed.

Cold Injury. This (figure 4) often appears on individual plants in the bed which are exposed by a tear in the canvas or by other means. In the springs of 1929 and 1931 cold injury was prevalent in plant beds, often affecting a majority of the plants. It occurred both years following cold, windy weather.

Figure 4. Cold injury to a White Burley tobacco plant in the plant bed, following a cold, windy night. The plant was transplanted for photographing. It recovered quickly when placed in the greenhouse. The same type of injury occurs on dark tobacco.

The bud leaves turn white, presumably because of injury to the chloroplasts, and the partially developed leaves appear constricted and white along the edges of the distal portion. Affected plants recover quickly and grow normally, following a rise in temperature, except that the affected leaves are mottled, and have somewhat the appearance of mild mosaic.

*Blotch or Scab.** This disease is characterized by the presence of olive-brown blotches on the upper leaf surfaces and stems of seedlings (figure 5A). It has been observed in Kentucky only on seedlings which are light in color. It is particularly prevalent in wet seasons on plants affected by black root-rot. If conditions which bring about susceptibility of the plants are corrected, the disease will be of no consequence. Beds of plants sowed with seed treated 20 minutes in water at 52°C were free from this spot whereas beds planted with the same seed

* Caused by the fungus, *Septomyxa affinis*.

untreated were affected. This suggests seed transmission of the fungus.

Anthracnose. In 1935, a leaf-spot was abundant in White Burley and dark tobacco in the Experiment Station beds which had been flooded several times (figure 5B). From these spots an anthracnose fungus (*Colletotrichum destructivum* was isolated and found by infection studies to be capable of causing similar spots. This fungus is quite common on clovers and alfalfa in Kentucky. The flood water had swept across a pas-

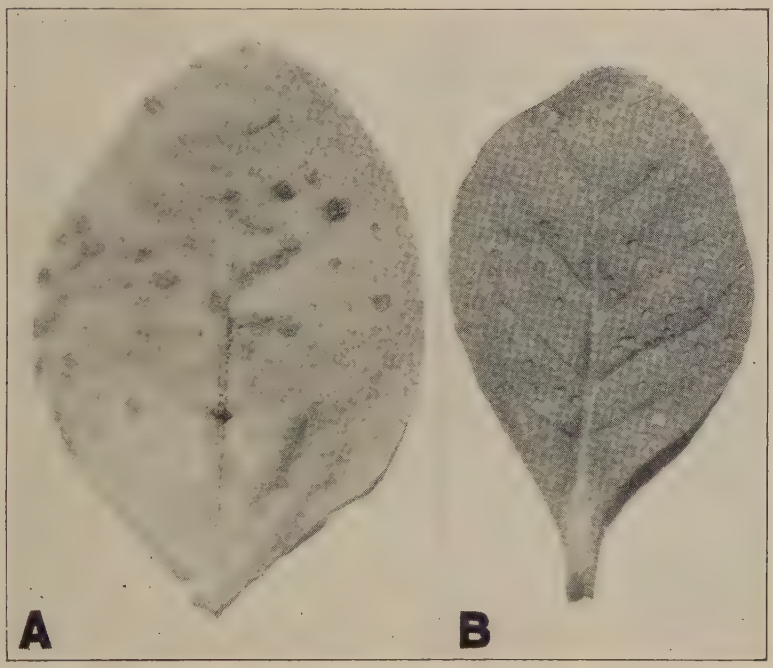

Figure 5. A. Scab. This disease is of common occurrence in plant beds. It occurs nearly entirely on leaves which are chlorotic or yellowish in color. The fungus appears to be growing on the leaf surface. B. Anthracnose on a leaf of White Burley.

ture in which several species of legumes were growing. It is not likely to ever become a serious plant-bed disease.

SEED TREATMENT

Seed treatments for the control of various diseases of to-

bacco, but more especially the bacterial leaf-spots, have been recommended from time to time. It is difficult to measure the benefit to be derived from seed treatment any one year but it is probable that the practice is of value every year altho the benefit may not be evident. Several seed treatments have been recommended or suggested as follows: 1. *Silver nitrate.* This is perhaps the safest treatment and as far as is known is as effective as any other. Seed is soaked for 15 minutes in a 1 to 1000* solution of silver nitrate in water, then drained and spread out to dry. Washing is not necessary. 2. *Formaldehyde.* Use 1 tablespoonful of formaldehyde to one pint of water, soak the seed for 10 minutes, wash in several changes of water and spread out to dry. 3. *Mercuric chloride* or *corrosive sublimate.*** Soak the seed for 15 minutes in a 1 to 1000 solution, wash thoroly, and spread out to dry. 4. *Hot water.* Tobacco seed may be treated at 52°C (125.6°F) for 20 minutes or longer, with benefit to germination and disease control. The treatment is more difficult than the silver-nitrate treatment and is not recommended for general use. Seed to be treated by any of the methods should be put in cloth bags and suspended in the chemical the required time. Seed may be injured in treatments 2 and 3 if washing is not thoro.

ROOT DISEASES

Black Root-Rot. The black root-rot organism*** attacks the tobacco roots either in the plant bed or the field, rotting them and eventually turning them black (figure 6). It may be particularly severe where tobacco is grown repeatedly in the same soil, or in plant beds where the same site is used several times without thoro sterilization. Injury in the bed may be so slight that diagnosis is difficult. In severe infestations the disease is recognized by slow growth of the plants and yellowing of leaves where there is no moisture deficiency, and by the presence of dead, blackened roots. In the Bluegrass section, the disease often is present in burned plant beds which are used a second

* 14 grains of silver nitrate to 1 quart of water.

** Tablets may be purchased, 1 of which to a pint makes the proper solution.

*** This disease is caused by the fungus, *Thielaviopsis basicola.*

Figure 6. Black root-rot of White Burley tobacco. A healthy root of a root-rot-resistant strain and the root of a susceptible variety grown in the next row. The short, stubby, black roots, with a few normal roots near the surface of the ground, are characteristic of a severe case of this disease.

time. It is often present in plant beds in Daviess County where the practice is to manure and use the same plant beds year after year. Satisfactory plants usually are grown in these beds because steaming sterilizes the soil to a sufficient depth to permit the plants to develop. However, many of the roots penetrate the infested layer of soil and the disease may thus be carried to the field. The common practice of using a new plant-bed site each year, is a means of avoiding black root-rot. Steaming permanent plant beds only sufficiently to control weeds, has not proved effective in freeing them from black root-rot. Unless steaming is thoro it should not be relied upon to sterilize infested soil. It is particularly necessary to change the plant-bed site frequently when the plants are to be set on limed soil or soil of low acidity, as in the central Bluegrass Region.

Black root-rot often is the cause of slow growth of tobacco in soil known to be in a high state of fertility, especially when

Figure 7. Two strains of White Burley tobacco highly resistant to black root-rot and, in the center, a variety of White Burley which is highly susceptible to the disease. All were pulled and set at the same time, in soil infested with the black root-rot fungus.

liberal applications of manure have been made (figure 7). In the Bluegrass section, if the fungus is carried from the plant bed to the field, it usually remains in the field indefinitely, and injures each succeeding crop. In the more acid soils of western Kentucky this organism does not become established so readily unless the land has been manured or limed and the organic matter content built up. On some of these acid soils infected plants from a diseased bed make as good growth as highly resistant plants of equal quality from the same bed. Where lime is to be used on tobacco land it should be applied following tobacco and in as small a quantity as will give the desired effect in growing legumes.

All the named varieties of White Burley and dark tobacco tested have proved highly susceptible to black root-rot in infested plant beds and nearly all of them are badly injured if set in infested fields.

In fields where the black root-rot fungus is known to be present and in fields which are being cropped with tobacco rather frequently a resistant variety should always be used.

In virgin soil any of the old standard varieties will prove satisfactory if plants are grown in a disease-free plant bed. The Kentucky Agricultural Experiment Station has developt a number of varieties of White Burley tobacco which are highly resistant to root-rot. One of these, designated No. 5, is now widely grown in Kentucky and has proved highly satisfactory. Plants of this variety are usually ready for setting about one week earlier than ordinary varieties and the plants frequently ripen a week to three weeks earlier. A resistant variety designated No. 7 regularly matures about a week earlier than No. 5.

Figure 8. Susceptible and root-rot-resistant White Burley tobacco. The field pictured was not known by the grower to be infested with black root-rot. A common variety (left) and a resistant selection (right) were grown side by side in several parts of the field, with results in each case similar to those shown above.

It has proved to be highly drouth-resistant but is perhaps slightly inferior in quality to No. 5. It has proved to be a satisfactory variety in Grant County and is worthy of trial in other parts of Kentucky. Another highly resistant variety, No. 16, is a more vigorous grower than No. 5, is of equal or perhaps superior quality and deserves trial.

Several strains of root-rot resistant White Burley which produce only a single sucker, instead of the usual two at each leaf, are available for trial.

Highly resistant strains of dark air-cured tobacco have been developed which have proved satisfactory in tests conducted in Daviess County for several years.

Resistant strains of a dark-fired tobacco are available for testing but cannot yet be recommended for extensive planting.

Prevention and control. Use a new bed site each year or steam a previously used bed at least 30 minutes, preferably 40. To prevent infestation of a field do not use plants from a diseased bed unless the field soil is very acid. If lime has been used on the tobacco land, use a new bed each year. Manure increases injury from black root-rot so that tobacco should not be grown in successive years on heavily manured land unless a resistant variety is grown. Use a black-root-rot-resistant variety of tobacco, if a satisfactory one can be obtained, whether the soil is infested or not, as it will reduce injury in an infested soil and prevent a clean soil from becoming infested.

*Brown Root-Rot** is a rot of the rootlets of tobacco plants in the field. It has not been observed to cause much injury in plant beds. The disease appears to be worse in soil of low available fertility. It may be present but appears to cause little injury in highly fertile soil. If the plants are severely attacked soon after setting, most of the rootlets will be found to be rotted back to the taproot and the growth of the plant is stunted for the greater part of the season (figures 9, 10). Recovery may come about thru development of roots from the crown and a fair crop may be produced. If infection is not severe, the plants may grow normally except that they wilt on hot days. If the roots of such plants are examined at any time during the growing season, numerous rotted rootlets will be found. Certain varieties show slightly greater resistance, as indicated by less wilting, than others, but the difference is slight when the disease is severe and at present the development of resistant strains does not seem to offer promise as a means of control. If

* The exact cause of the disease is not known, but in Kentucky it appears to be a Pythium, probably the same one which causes root-rot of corn in this and other states. A Pythium is isolated readily from the rotting tobacco rootlets, and in the greenhouse the Pythium which causes corn root-rot causes extensive injury to tobacco roots.

the susceptible White Burley varieties (those wilting the most) have made fairly normal growth, they often make a better quality of leaf than the slightly more resistant varieties. The disease has been severe after corn, alfalfa, soybeans, and timothy on the Experiment Station farm at Lexington and, if this occurs elsewhere, the rotation should be arranged so that tobacco does not follow these crops. The disease does not appear to become worse with frequent cropping to tobacco; a tobacco crop following a diseased one may be nearly free from the disease. Brown root-rot apparently does not affect tobacco seriously following a good bluegrass sod, red clover or a heavy growth of weeds. Whereas some investigators believe that turning under a sod may cause brown root-rot, experience in Kentucky indicates that the disease occurs most frequently on heavily pastured land and not where a heavy sod has been turned under.

Prevention. If favorable crop rotations are followed, the soil is well supplied with organic matter, and a liberal amount

Figure 9. A portion of a field of White Burley tobacco affected with brown root-rot. The field had been in corn for the previous ten years thus indicating a crop relation between the root disease of corn and of tobacco. Photographed September 2, 1923.

of commercial fertilizer is applied, injury from brown root-rot should not be serious.

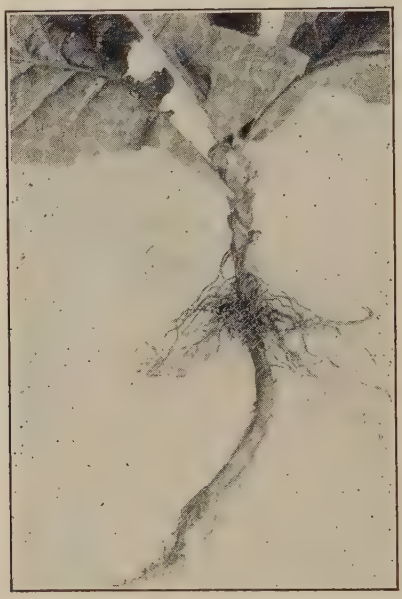

Figure 10. Brown root-rot of White Burley tobacco from the field shown in Figure 9. Nearly the entire active root system has developt near the soil surface.

Root Knot. This is caused by nematodes, or round worms. It is found occasionally in tobacco plantings in Kentucky. The tobacco roots and rootlets are enlarged at irregular intervals which cause them to have a more or less beaded appearance. If the knots are broken open carefully, the small, white, spherical, female worm may be found in the knot. The disease probably occurs most commonly on tobacco growing on land previously used for a garden. Nematodes are frequently introduced into garden soils on tomato plants grown in the greenhouse or shipped from the South.

Control. Root knot is not serious in this State and requires no special precautionary measures, but should it become serious it can be greatly reduced by growing crops which are resistant

for two or more years. Many weeds are affected by nematodes; therefore the resistant crops should be kept as weed-free as possible. Corn, wheat, and some other grasses are resistant and Brabham and Iron cowpeas, as well as some other hybrids with Iron, are highly resistant.

Club-Root. This is a rather rare disease of tobacco. The first leaves of an affected plant are normal but succeeding leaves

Figure 11. A plant of cigar tobacco showing the kind of growth typical of club-root. Photo by F. D. Fromme, Germantown, Ohio, August, 1927.

are progressively shorter. This, with the shortened stalk, gives the plant a squat, pyramidal appearance (figure 11). The leaves appear rigid and stand out nearly at right angles to the stalk. The internodes of the flower stalks are short. The roots of such plants are always enlarged and have the general appearance of cabbage roots affected with club-root* (figure 12).

* The disease is not caused by nematodes, as a thoro search failed to reveal their presence. These findings were confirmed by Dr. N. A. Cobb, of the Bureau of Plant Industry, Washington, to whom specimens were sent on two occasions.

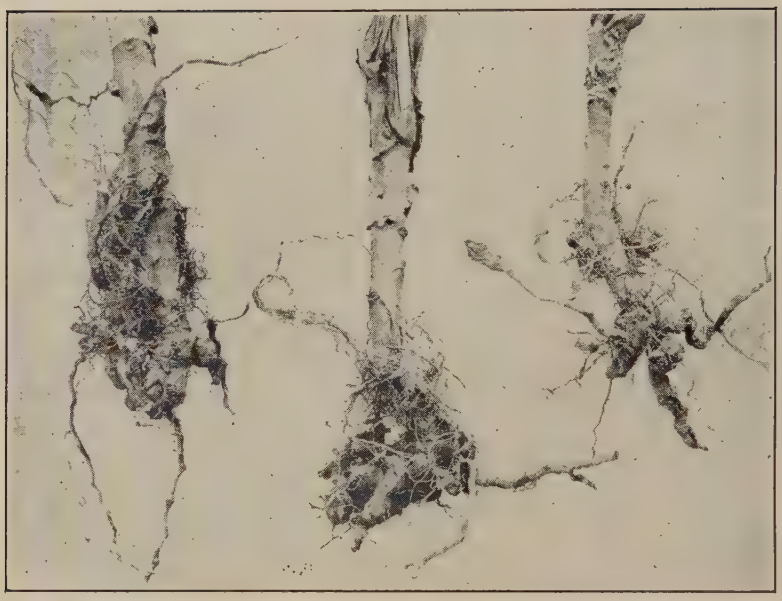

Figure 12. Club-root of tobacco. Nothing is known as to the cause of this rather rare disease. While it has much the appearance of root-knot, nematodes are not found in the roots. Specimens from Campbell County, August 16, 1922.

The first specimens of plants affected with club-root were received by the writer from County Agent H. F. Link, Alexandria, Campbell County, in August, 1922. The disease has also been found affecting both White Burley and air-cured dark tobacco on a farm near Owensboro, Kentucky, and has been found in Fayette County. The cause of the disease is not known, and little is known as to its occurrence in Kentucky. Undoubtedly it has been confused with nematode injury. Considering the long time that tobacco has been grown in Kentucky and the rare occurrence of the disease, it is not likely to become serious.

Broomrape. This is a parasitic flowering plant (*Orobanche ramosa*) which grows upon the roots of tobacco, hemp and other plants (figure 13). It is incapable of forming green coloring matter, and therefore cannot elaborate its own food materials

but takes them directly from the roots of the plant upon which it lives. It produces seeds in abundance which are capable of remaining in the soil for many years in a viable condition; consequently broomrape may appear in fields which have not been planted to either tobacco or hemp for a very long time. The parasitized tobacco plants take on a sickly, yellowish, starved

Figure 13. Tobacco parasitized by a plant of broomrape (*Orobanche ramosa*).

appearance, at which time large masses of the blue-flowered broomrape can be seen around the base of the tobacco plant. The broomrape, which is very injurious to tobacco in the Blue-grass section of Kentucky, is supposed to have been introduced

with hemp seed when hemp was widely grown in that part of the State.

Prevention. No way is known to prevent broomrape in fields known to be infested. Avoid planting tobacco in them. In a mild infestation it would probably be well to pull the broomrape plants from the roots of tobacco before the broomrape seeds develop. This would prevent further soil infestation, and benefit the tobacco.

LEAF DISEASES

Angular Leaf-Spot. This bacterial disease,* sometimes called rust in the White Burley section, is widespread in Kentucky and in certain years is the cause of considerable injury to tobacco. The disease appears in the plant bed rather suddenly, on tender, rapidly growing plants, as water-soaked spots on the under side of the leaves. These spots rapidly turn brown, which gives the plants a scorched appearance. Following a severe outbreak, the plants usually recover rapidly and as the earlier affected leaves die, the plants may show but few signs of infection at setting time. The spots on older leaves have small, irregular, nearly black centers, surrounded by a narrow halo or band of yellow (figure 14, A). With age the centers may turn nearly white. The tissues around the spot, especially on plants in the bed and on rapidly growing tobacco in the field, are often puckered and torn. The disease is generally present in White Burley plant beds where it sometimes causes considerable injury if the plants are small. Dark tobacco appears to be more resistant to the disease. It is difficult to find angular leaf-spot on dark tobacco plants even when they are growing in the same bed with heavily infected White Burley plants. The disease is carried to the field on young plants where it may spread rapidly, during rainy, windy weather.

The spotting of White Burley tobacco which occurs in wet seasons on poor soil areas, especially following the last suckering, and the disease of dark tobacco characterized by the presence of concentric rings do not seem to be caused by the angular leafspot organism. Spots of this type have frequently been

* Caused by the organism *Bacterium angulatum.*

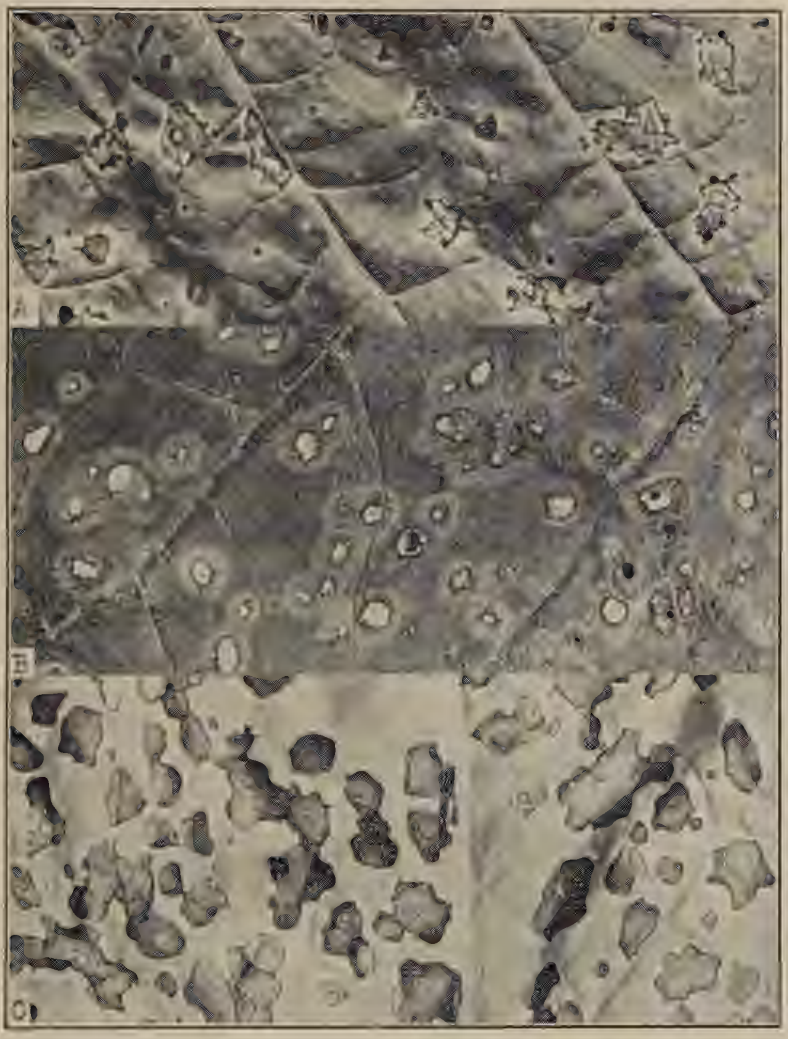

Figure 14. Three leaf-spot diseases of tobacco. A. Angular leaf-spot. B. Wildfire. These are two bacterial diseases which are sometimes destructive to tobacco. C. Rust, or blackfire, as it occurs on White Burley tobacco.

shown to be free from pathogenic bacteria. In a wet season, when angular leaf-spot has spread rapidly about topping time when the plants are very susceptible, it is often difficult or impossible to distinguish between the two diseases. Until angular leaf-spot can be completely eliminated from dark tobacco fields, it will be difficult to determine the extent of injury caused by the physiological disease. This type of spot is discussed under the heading "Blackfire and Rust."

All the ways in which the angular leaf-spot organism overwinters are not known. Sometimes the bacteria appear to overwinter in bits of trash mixed with the seed and can certainly overwinter in tobacco trash in the barn, but these sources do not seem to explain all cases of plant-bed infection. Three years in succession, beds on the Experiment Station farm sowed with seed raised in the greenhouse, and therefore thought to be entirely free from infection, and handled with every precaution to prevent accidental infection, were found to be extensively infected before pulling time. In 1929 the bed was extensively infected with wildfire also. The beds were plowed out of bluegrass sod, and so located as to be away from any danger of contamination from previous crops, other than wind-blown material. Experience seems to indicate that the bacteria which cause angular leaf-spot are practically always present in White Burley tobacco plant beds everywhere in Kentucky and to a less extent in dark tobacco beds. The beds may remain apparently free from visible signs of infection until the plants are well developt and then, in the course of two or three days, the disease may break out in all parts of the bed in a severe form. The conditions which bring about these sudden outbreaks and the source of the bacteria which cause them are not well understood. It has been observed frequently that the first sign of disease in a tightly boxed bed is near a tear in the canvas. A leaf protruding thru the tear may have numerous spots near the tip. These have the appearance of having been infected by an insect crawling over the under surface of the leaf. A possible explantation is that the bacteria are introduced by insects from some native plant. This theory is supported by the fact that

smooth and clammy ground-cherry plants, growing in fencerows and in pastures on the Experiment Station farm, were found to be heavily infected with the angular leaf-spot organism late in the fall of 1935. This weed appears to be as good a host for the organism as tobacco.*

While it is generally believed that field infection always originates in the plant bed, this has not been clearly demonstrated; and control of the disease in the bed may not prevent field infection. Plants from the 1931 and 1935 beds, on the Experiment Station farm, not visibly affected with angular leaf-spot at setting time, soon develop infection after setting in the field.

Prevention. In view of the limited knowledge of both angular leaf-spot and wildfire no recommendations can be made which would assure freedom from infection in the plant bed. Measures which may be of value in reducing plant-bed infection are: The use of two-year-old seed, which appears to be free from infection or of treated seed; the use of new or boiled canvas or of canvas which has been stored away from all tobacco trash; locating the plant bed so that tobacco trash from the barn will not be washed, blown, or carried into the bed; abstaining from carrying natural-leaf cured tobacco to the plant bed in the pockets; boxing beds and covering them securely with cotton so that they will be insect-proof; and drenching the beds, when the plants are small, with Bordeaux mixture. One application when the first true leaf is just forming is sometimes effective but a second application 10 days later is desirable.**

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* Since this bulletin was written, studies by the authors have shown that both the angular leaf-spot and wildfire organisms can be transferred from plant to plant of rapidly-growing tomato, pepper, jimson weed, soybean, and cowpea, where they multiply as rapidly as in tobacco and cause spotting typical of the organism concerned. It seems evident that the organisms are not limited to species of tobacco as the only hosts.

** Bordeaux mixture is cheap and is easily applied with a sprinkling can. It should be applied while the plants are small and before the disease appears. Bordeaux mixture suitable for sprinkling on tobacco plant beds is prepared as follows: 50 gallons, sufficient for 66 yards of bed 9 feet wide, require 4 pounds of chemical hydrated lime (or 3¼ pounds of stone lime slaked with a small quantity of water), 3 pounds of finely powdered copper sulfate (bluestone), and 50 gallons of water. Dissolve the bluestone in a bucket of water. Mix the lime into a thin paste with water in another bucket, and pour it into the water in a barrel or other container, containing about 46 gallons of water. Then, while stirring vigorously, pour in the copper sulfate solution. The Bordeaux may be prepared in a wooden barrel, or 60-gallon oil barrel, and may be applied to the bed with an ordi-

Wildfire is a term used incorrectly by tobacco growers to indicate any leaf disease which spreads rapidly thru the field. It should be used to designate the bacterial leaf-spot disease* characterized by the development of lemon-yellow spots on the leaf (figure 14, B), usually about 3/8 of an inch in diameter. These spots are so characteristic they can readily be distinguished from any other disease in the plant bed or when spreading rapidly in the field. A small dead area develops in the center of the yellow spot and other dead areas may develop near the margin of the yellow area.

The disease may be destructive but it has occurred only occasionally in the past 9 years, in Kentucky. It was found in Calloway County about 1928 where it has gradually increased until, during the past three years, it caused extensive damage to plant beds in the form of soft rot of small plants. It was found on two farms in Graves County in 1932 and specimens have been received from that county several times since. It has been seen on the Experiment Station farm at Lexington from time to time since 1920 but usually only a few spots were found in the plant bed or on one or two plants in the field. Why it has never become serious is difficult to explain. In 1935 the disease appeared in plant beds and fields in the southern counties in the dark-fired district of western Kentucky and was found for the first time at the Western Kentucky Experiment Substation.

The life history of the organism is probably identical with that of the angular leaf-spot organism but the disease has never been so prevalent in Kentucky as angular leaf-spot. In Pennsylvania groundcherries growing near diseased tobacco plants were found to be infected with wildfire, but the weeds were not considered to play any part in the life history of this tobacco disease. In Kentucky the wildfire organism was found to be present with the angular leaf-spot bacteria in a groundcherry leaf, but in such a small amount that the first inoculation

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nary sprinkling can. It is best to wash out the containers before use, so that the sprinkler will not become clogged. The mixture should be stirred every time a portion is removed from the barrel.

* Caused by *Bacterium tabacum.*

to tobacco produced only angular leaf-spot. When single colonies of bacteria were studied, one of them caused typical wildfire. The recommendations for prevention of angular leaf-spot should be equally effective for wildfire.

Blackfire and rust are terms used by growers in referring to the spotting of dark and White Burley tobacco, which occurs late in the season. Any burned condition of the leaves is also called rust. While the terms, angular leaf-spot and blackfire, are used interchangeably in some of the literature, it seems preferable to retain the name, blackfire, for the late-season disease of dark tobacco, as the growers have referred to the disease by this name for many years, and use angular leaf-spot as the name of the disease which occurs earlier in the season and is without question caused by bacteria. Further study may prove that the destructive disease of ripening tobacco, here called blackfire, is caused by the angular leaf-spot organism; if so, it will be proper to use the term blackfire for the early and late season diseases. At present the cause of blackfire is uncertain and the terminology here used seems preferable.

Blackfire is undoubtedly the most destructive leaf-spot disease in western Kentucky during wet seasons and is the so-called rust of White Burley, which is very destructive in wet seasons, following topping and suckering. Spotting is more prevalent in low, wet places and in eroded areas, and is usually nearly absent in fields of high productivity, especially when the physical condition of the soil is favorable. The spots begin as water-soaked areas which appear over night. They increase in size forming target-like spots as the newly killed tissues dry (figure 14 C). Many of these concentric spots have been found by isolation studies to be free from bacteria of any sort. From others the angular leaf-spot or wildfire organism has been isolated. It may have been present as a contaminant.

This spot is reported by growers to spread after the tobacco is housed, an occurrence which appears never to be the case with angular leaf-spot and wildfire. Water-soaked spots have appeared over night on leaves from plants grown in an affected

field, and kept in the laboratory with the base of the leaf in water. A similar spot sometimes begins on the lower side of leaves which have been turned over by wind during a rain storm. Examination has generally shown them to be free from bacteria. In the dark-tobacco sections striking instances of freedom from blackfire have been observed where heavy applications of well rotted stable manure had been used or where organic matter from other sources had been introduced into the soil. Likewise manure appears to have a beneficial effect in reducing this disease on White Burley tobacco. Treatment with a liberal application of a fertilizer containing nitrogen, phosphorus and potassium has had a marked effect in reducing the disease in rotations on certain of the soil experiment fields. Methods of handling the White Burley crop appear to influence the severity of the disease. Plants topped low and kept closely suckered may be susceptible to injury, whereas plants left untopped, or topped and one or two suckers allowed to develop, may remain free from spotting until topped or suckered. If the tops or suckers are removed during a rainy period, the tobacco may be damaged extensively in two or three days. A prevalent belief of tobacco growers is that as long as tobacco is making good, uniform growth it is not subject to this type of leaf spotting. Because of experiences of this kind some Burley growers have adopted the practice of not topping the tobacco until cutting time, and others top but allow one or two suckers to develop in the top of the plant until cutting time. The plants are then suckered and cut immediately.

Prevention. As the disease appears to be the result of faulty nutrition, prevention will probably depend on a soil-building program which will include legumes, and on liberal use of mixed fertilizers.

Frogeye and Greenspot. Frogeye, which is caused by a fungus,* is common in Kentucky but is rarely the cause of serious injury to tobacco. The spots are found on the lower leaves in damp locations. They have a dead, white, parchment-

* This disease is caused by the fungus, *Cercospora nicotiana.*

like area in the center, about 3/16 of an inch in diameter. In this area is an indistinct grayish mass of spores (figure 15).

Figure 15. Frog-eye of White Burley tobacco. The parchment-white spots with the gray centers are typical of this disease.

The tissue surrounding the spot is a light orange yellow blending into the normal green of the leaf. As the yellow area sometimes becomes quite wide, the spots might be confused with wildfire. The disease is usually considered to benefit White Burley tobacco when it affects only the lower leaves; but in 1934 and 1935 the upper leaves of White Burley tobacco were found to be peppered with small green spots after the tobacco was cured (figure 16). These are believed to be late frogeye infections. Very little is known of the life history of the organism and satisfactory methods of prevention are not known. Some evidence suggests that the fungus is seed-borne and that the disease may be prevented by seed treatment. To reduce the amount of greenspot,

Figure 16. Greenspot on a cured leaf of White Burley tobacco. This spot is supposed to be caused by late infections of the frogeye fungus.

it is desirable to dry the surface of the leaves of tobacco as quickly as possible after they have been hung in the barn. This may be done by efficient ventilation combined with proper firing during the yellowing period, if the air is very moist.

Leaf Scald. Every year scalding of White Burley tobacco leaves may be observed. In 1930 it was prevalent in early, rapidly growing tobacco which had attained considerable size before the drouth became severe. The scalding, which usually occurs on about two leaves of a plant, develops while the leaves

are badly wilted. The parts of the wilted leaf folded together and exposed to brilliant sunlight fail to recover, turn a bluish-green color and later dry and turn brown (figure 17, A, B).

Figure 17. Leaf scald of White Burley tobacco. A. Two leaves badly wilted. Wilting of this kind is usually attributed to the sting of an insect. B. A leaf such as is shown in A following recovery from wilting. Some parts of the leaf were so badly wilted that death followed. The dead areas are at first bluish green and later turn brown.

A greenish black mold develops over the surface of the dead tissue. In 1930 the chief cause of wilting appeared to be lack of water. According to observations of growers wilting is sometimes

caused by the sting of one of the stink-bugs. If the bark is carefully peeled from the stalk of a wilted plant white, elongated areas of collapsed spongy tissue may be found. These are evidently the feeding areas of the stink-bug. No preventive measures are known.

VIRUS DISEASES

Mosaic. There are many virus diseases of tobacco; the most destructive of them is tobacco mosaic (figure 18). This disease is present wherever tobacco is grown. It is known to most tobacco growers, altho often by some other name than mosaic. In some parts of Western Kentucky it is called walloon; in other parts of the State, black french, dry-weather french, frenching, etc. The disease is characterized by a mosaic pattern of light and dark green areas in the leaves which develop after infection occurs. The tobacco mosaic virus appears to be quite variable. As a consequence, there are numerous strains of the virus and affected plants differ greatly in symptoms. Certain strains cause mild mottling and no distortion of leaves and others prominent mottling and distortion of the new leaves. The patterns may be pure white or yellow or various shades of green. Certain strains are characterized by causing burning or spotting of leaves, a condition known as *mosaic burn* (figure 19). Other strains never cause burn. Burn is confined largely to leaves which are too old to develop mottle patterns but which have not yet reached full size. When a burning strain of mosaic is spread during topping one or two upper leaves may burn with no other symptoms of mosaic except in the suckers. Mosaic burn may cause extensive injury to tobacco on one farm and be entirely absent on another farm where a non-burning strain is present. Mosaic burn is frequently confused with rust or blackfire by the grower and he may commence cutting to prevent further spread. This is not necessary.

The cause of the disease is a virus, particles of which are too small to be seen with a microscope, but which are readily transferred from diseased to healthy plants by handling one and then the other. Recently a crystalline protein, possess-

Figure 18. Mosaic of tobacco. There are several distinct strains of the typical tobacco mosaic which differ in severity of the symptoms produced on the plant and in the color produced in the affected leaves. Usually the affected leaves are various shades of green but one strain produces yellow blotches while another turns parts of the leaf almost white. A mild and a severe form of mosaic are shown here.

ing the properties of tobacco mosaic virus, has been isolated from Turkish tobacco plants diseased with this virus. It is possible, therefore, that this virus may be of the nature of an autocatalytic protein which causes the production of more of the virus when placed in a favorable medium, as the cells of a tobacco plant. If this is true, it means that the protein (virus) is produced from substances within the cell in the presence of virus particles which direct the course of certain chemical reactions resulting in more of the virus.

The virus has been shown to remain active for 52 years in cured tobacco. Hence it is practically always present in the natural-leaf chewing or smoking tobacco used by tobacco growers. As the disease is readily transferred from dried tobacco to living plants, the tobacco grower himself is nearly always the chief agent in introducing the disease into the plant bed or field. It has been clearly demonstrated that a man who uses natural-leaf tobacco contaminated with the virus, either for chewing or smoking, may transmit the disease readily to healthy plants while he is weeding, or pulling plants for setting. Once introduced, the disease is easily spread during operations in which the plants are handled, such as pulling, worming, topping, and suckering and by cultivation. In a field where the disease was prevalent earlier, many of the suckers are likely to be diseased following cutting. The virus does not appear to be carried in tobacco seed.

Certain weeds (horsenettle and groundcherry) become infected and carry the virus from year to year. But these appear to be minor sources of the mosaic virus as compared with man. The disease is spread slowly from the weeds to tobacco, perhaps by insects, during the summer; hence it is practically impossible to completely prevent its occurrence in fields where infected weeds are prevalent. To remove the weed hosts of mosaic in and about a tobacco field any one year may not be practicable but an aggressive campaign against these weeds may in time prove valuable. These weeds are potential hosts not only for tobacco mosaic, but for other viruses which affect vegetables, as cucumbers, tomatoes, and potatoes. If a

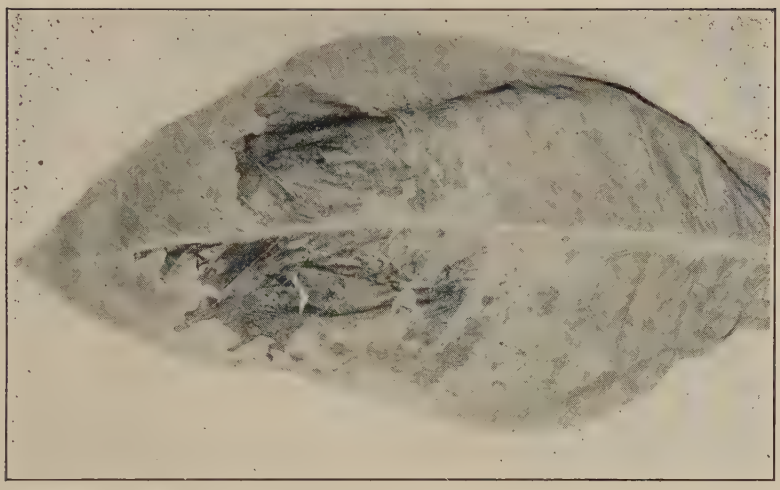

Figure 19. Mosaic burning. This type of injury often develops on one or two leaves of a plant recently infected with certain strains of tobacco mosaic. Few tobacco growers recognize this as a symptom of mosaic because at the time these symptoms appear the mosaic symptoms may not be in evidence, especially in topped tobacco.

tobacco bed is made in an area where horsenettles and groundcherries infected with mosaic are abundant it is possible while weeding the bed to spread the disease from these weeds to an occasional tobacco plant. If this occurs, mosaic may be abundant in the field later on. While the problem of plant infection from weeds has not been studied it is probably best to make it a rule never to remove either of these weeds from the bed and never to touch them while pulling plants. Infected and healthy plants may grow side by side for weeks, without the disease spreading, if the plants are not handled.

Extensive field infection may result from chopped tobacco stalks and other tobacco trash known to carry the mosaic virus which has been applied to the field at the last disking before setting. Tobacco stalks, unless they come from a field known to be relatively free from mosaic, should not be used as a fertilizer for tobacco.

In Kentucky overwintered roots, of affected tobacco plants, retain some of the virus; but thus far no greater difficulty has been encountered in preventing mosaic in plots on the Experi-

ment Station farm set to tobacco each year, than in plots set to tobacco at less frequent intervals. It therefore seems safe to grow tobacco two or more years in succession without fear of extensive infection if the proper precautions to prevent infection from other sources are taken.

Growers frequently express the opinion that mosaic does not injure tobacco. This is not true except in White Burley where no injury may result if infection occurs shortly before cutting. There is some evidence that White Burley may be slightly improved in quality by late infection. Infection of either White Burley or dark tobacco at setting time reduces the value of the crop about 60 percent, and infection when about half grown, by about 50 percent. When plants are inoculated at topping time, both dark and Burley may be injured about 25 percent if the White Burley is topped early. Contrary to popular belief mosaic patterns which are present in green tobacco are still visible in the cured leaf (figure 20).

Prevention. Satisfactory control of mosaic, under Kentucky conditions, appears quite simple. Exclusion from the plant bed of all tobacco trash of previous year's crops, such as ground tobacco stalks and trash used as fertilizer, and complete abstinence from the use of natural leaf tobacco during the weeding and setting season by those who handle the plants, usually gives control. Before going to the plant bed all tobacco should be removed from the pockets and the hands should be thoroly washed with soap and water. Tests of commercial tobacco indicate that manufactured twists and scrap are probably always free from mosaic, and plugs rarely carry it. Cigarettes and tinned smoking tobacco, while they carry mosaic, have been proved relatively safe to use. Therefore any of these types of tobacco may be substituted for the natural-leaf tobacco during the plant-bed season with a fair degree of safety. Horsenettles and groundcherries should not be handled while weeding or pulling plants. Mosaic may be introduced and spread while worming tobacco by hand. Therefore, it is preferable to control the tobacco horn-worm with poison dusts.*

* See Kentucky Extension Circular 230 (Revised), page 19.

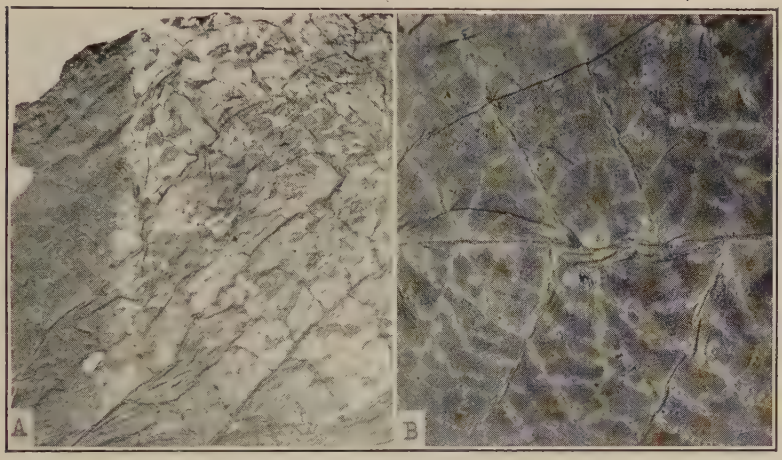

Figure 20. A. Tobacco mosaic patterns in a cured leaf of dark fired tobacco. The portion with patterns was taken with transmitted light and the remainder with reflected light. Leaf for photographing furnished by J. F. Freeman and Russell Hunt. B. A portion of a cured leaf of White Burley tobacco showing mosaic patterns with reflected light.

A much higher proportion of plants become infected with mosaic if worming is done when the plants are damp than when they are dry. It is preferable, therefore, if mosaic is present in the field, or if one uses natural-leaf tobacco for chewing and smoking while handling plants, to handle them only when dry. Mosaic may be spread from plant to plant by tools and harness while cultivating tobacco. It is therefore a good practice to go thru the field about one month after setting and remove all diseased plants. Healthy plants should not be handled during this operation or until the hands have been thoroly washed. If mosaic plants are present in a field of dark tobacco at topping time they should be topped last. It is not so necessary to observe this precaution with Burley tobacco especially if it is topped late. It has been found that mosaic burn on the top leaves of White Burley plants may improve their quality somewhat. Fields of Burley tobacco heavily infected with mosaic should be topped late. If topping is done with a knife and only the top of the plant is handled, there will be little

Figure 21. Ring-spot of tobacco. A. A leaf from a plant in the bed evidently infected thru the seed. B. A leaf from the field. The dead lines, often in the form of rings, are characteristic of the disease.

spread of mosaic. If these simple precautions are taken, damage from mosaic will be negligible.

Ring-Spot. Perhaps the most common and easily recognized of the virus diseases of tobacco, other than mosaic, is ringspot. The name characterizes the disease quite well, as frequently dead rings occur, altho the symptoms vary greatly (figure 21). Sometimes the disease is destructive to individual plants, but is not very injurious except in occasional fields during certain years. It is questionable whether this virus disease will become severe enough to make preventive measures necessary. Ringspot is found in nearly every tobacco crop examined. It has a wide host range. It may overwinter in horsenettle, groundcherry, sweet clover, and probably in several other weeds from which it may be transmitted to tobacco by insects. The virus does not remain active in the cured leaf. It is carried in seed from affected plants and develops in an occasional seedling altho the ring symptoms may not appear. It is the only virus disease which is quite commonly present in a plant bed in which plants have never been handled.

The first symptoms may appear on tobacco plants in the bed (figure 21), A) or on plants in the field almost as soon as growth commences following setting. With the exception of tobacco mosaic, it is the first virus disease to be recognizable in tobacco fields following setting. The disease spreads gradually during the remainder of the season. If measures for prevention become necessary in certain fields, eradication of the weeds which prove to be the most potent sources of infection, and the use of seed from healthy plants should be the first precautions. The disease is widespread in the State, and appears to be a common cause of mosaic in cucumbers. It sometimes affects potatoes also.

Streak. Rarely a tobacco field is seen in which large plants are practically destroyed by what appears to be a severe type of virus disease (figure 23). The disease might be called streak because of its similarity to the virus disease of tomatoes known as streak. The streaks consist of long, dead, depressed areas which extend down the stalk but which often originate on the

underside of the midvein of a leaf. Those leaves on the plant when it becomes affected may yellow and die and the new leaves may be much distorted and peppered with small, brown spots. A similar disease has been produced on half grown White Bur-

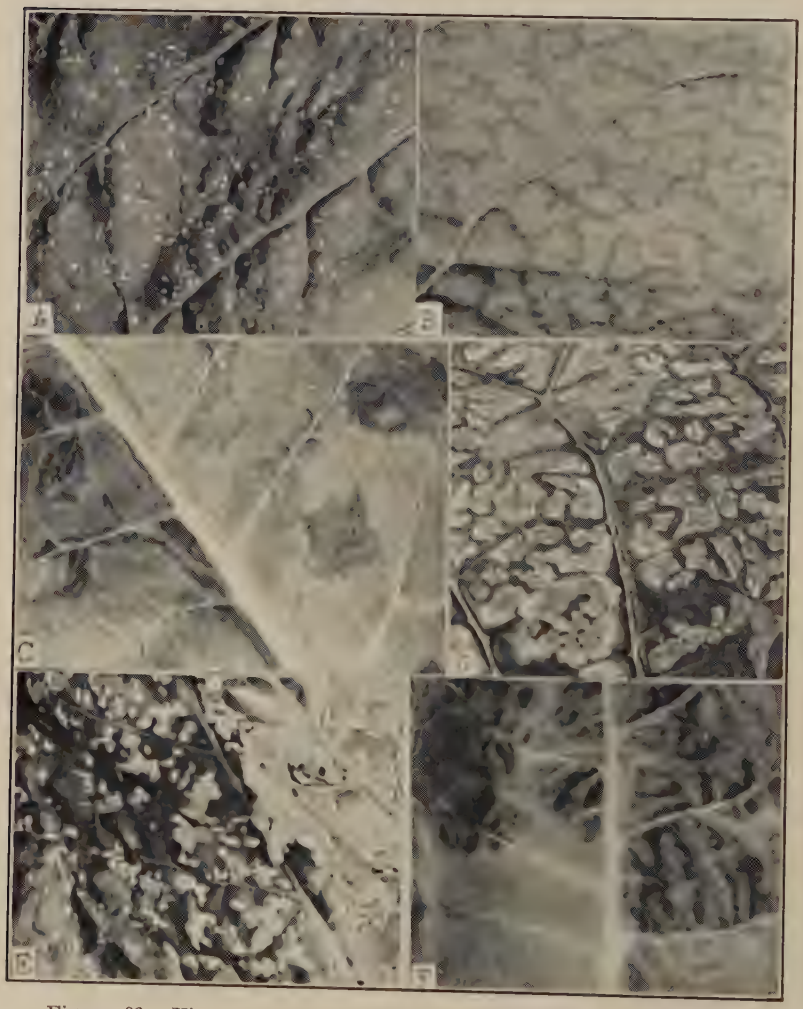

Figure 22. Virus diseases of tobacco. A Speck-spot; B. Vein-banding; C. A mosaic which can be transferred to cucumber but which differs from the typical cucumber mosaic. D. Yellow tobacco mosaic. E Coarse etch; F. Typical cucumber mosaic.

ley tobacco plants by inoculations with tomato tissue from plants which had a severe form of virus disease and by inoculation with any strain of the tobacco mosaic virus which causes necrotic or dead spots at the points of entrance of the virus.

Speck-Spot. A white or light brown specking of tobacco is frequently seen. It appears to be the result of virus infection. It has been found associated with several of the tobacco virus diseases but has not been observed on plants free from infection (figure 22, A).

Other virus diseases. There are several other viruses which affect tobacco in the field but which are usually not very injurious. Several viruses, similar in nature to the cucumber mosaic virus, affect tobacco (figure 22, C, F). There are three viruses, differing in degree of severity, called the etch viruses, which affect tobacco. The vein-banding virus, commonly present in mosaic potato plants, attacks tobacco (figure 22, B). These and some other virus diseases of tobacco seem to occur most fre-

Figure 23. Streak of tobacco. This disease, while not prevalent, is very destructive to tobacco when it occurs. The concentric patterns in the pith are an unusual symptom of a virus disease.

quently in potato-growing areas. Experimental evidence indicates that several of them (vein-banding, etch, and typical cucumber mosaic) may be carried from generation to generation in potatoes. While these diseases may affect a high percentage of plants in areas where potatoes are regularly grown they do not seem to cause enough injury to be observable in the cured tobacco.

STALK DISEASES

Fusarium Wilt. Wilt has been observed or reported many times in Kentucky. It is largely confined to sandy soil where

Figure 24. Fusarium wilt of White Burley tobacco caused by inoculation with a pure culture of the fungus at setting time.

it spreads rapidly and persists for years. While the fungus* which causes the disease appears to be widely distributed in the more fertile soils of the State, it rarely causes injury to tobacco growing in them. Attempts to infest soil on the Experiment Station farm at Lexinton were not very successful. In soil which was contaminated three years in succession with virulent strains of the fungus, highly susceptible White Burley plants were grown with only 1 or 2 percent mortality. The disease is

* *Fusarium oxysporum* var. *Nicotianae.*

therefore not likely to become a factor in the better soils of the State.

Affected plants are usually scattered in the field, but there are instances of all the plants in a large area being destroyed. If present in one crop it is likely to affect a much larger number of plants in the next crop set in the same field. It is more prevalent in White Burley than in dark tobacco but has been seen in the latter. The fungus enters a single root and spreads from it up the side of the plant and causes the leaves on that side to turn yellow, wilt, and die (figure 24). The rest of the plant may remain fairly normal altho it may bend toward the diseased side. If the stem of an affected plant is cut across, the veins on the wilted side will be found to be discolored.

Prevention. The disease does not cause sufficient injury to dark tobacco to warrant preventive measures. The varieties of dark tobacco tested proved to be more than fifty percent resistant when inoculated at setting time. Two varieties of White Burley tobacco have been developed at the Kentucky Experiment Station which are about 50 and 75 percent resistant to wilt, respectively. Seed of these varieties is available for trial, and should be used when fields known to be contaminated are to be cropped with Burley tobacco.

Lightning Injury. Lightning frequently strikes in a tobacco patch and kills young plants. A circle of plants sometimes as large as fifty feet in diameter may be struck. The plants in the center may be killed to the ground line, but the roots remain uninjured. The plants on the border of the affected area may show little injury. The whole area has the appearance of a spot in which a disease is spreading very rapidly from a center and for this reason often causes alarm when first discovered. When lightning strikes in a patch of topped tobacco the stalk of an occasional plant may be killed and the tissues torn from between the secondary veins of the basal third of the leaves. Plants showing all degrees of injury may be irregularly scattered over the area (figure 25). The injuries are quite characteristic. The large leaf veins and the stalk are most subject to injury. The affected portions of the veins turn black and shrink giving

the blade a pleated or gathered appearance (figure 26, B, C). The stalk may have sunken, dark-colored, areas on it or if completely killed may shrivel and become hard and leathery (figure 26, A). It is a peculiar fact that the stalk and midveins may

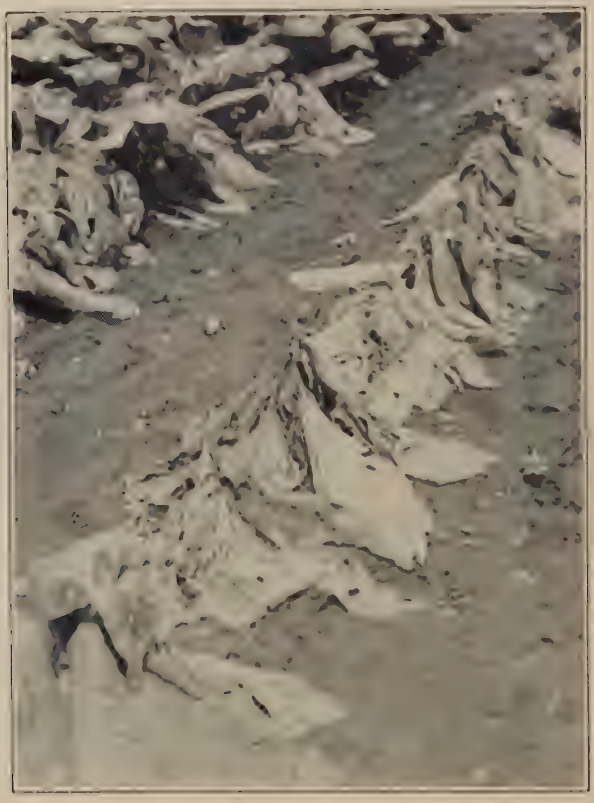

Figure 25. Lightning injury to White Burley tobacco. The photograph was taken three days after the tobacco was struck.

be shriveled and dead and the leaves go on living normally for days, apparently because the root is unaffected and the water channels of the stalk remain open even tho the stalk is dead. If a stalk is split open after it has dried somewhat, the pith will be found to be separated into disks, which gives a peculiar ladder-like effect (figure 26, A).

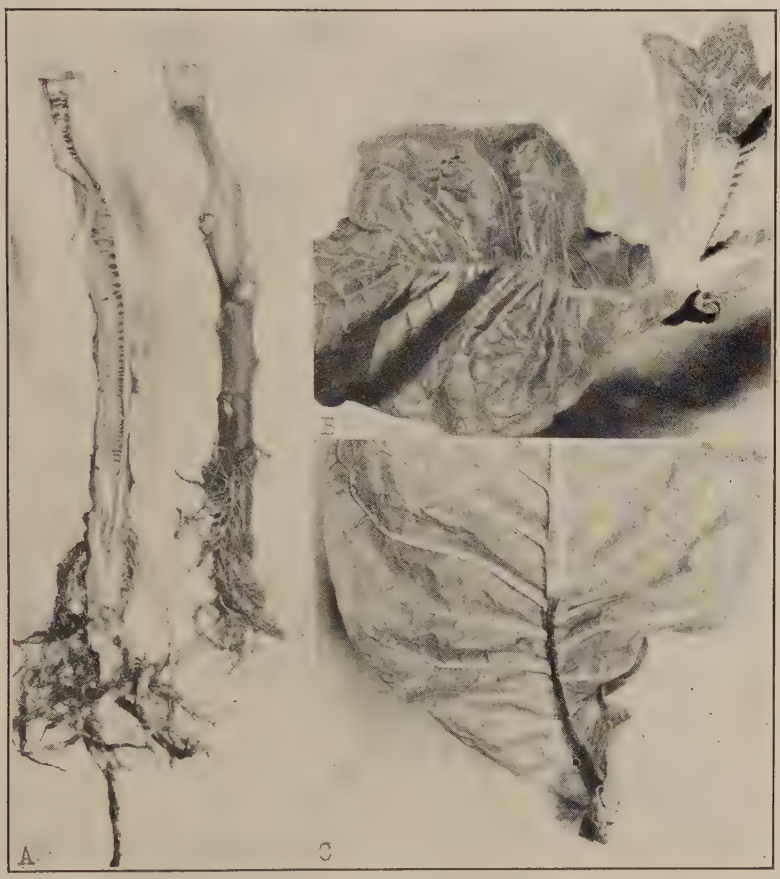

Figure 26. Lightning injury to tobacco. A. The shrunken stalk and separation of the pith into disks give a ready means of identifying lightning injury. B. The midveins of the bud leaves have been partly killed but in the large leaf the midvein is completely killed, giving the "gathered" effect. C. The lower portion of the midvein has been killed. The death of the midvein does not destroy the leaf which it supplies.

Sore-Shin. Tobacco plants are sometimes affected with a disease which causes blackening of one side or of the entire stem near the ground (figure 27). It may spread up the stalk some distance. The lower leaves droop and finally the plant is killed. The disease is somewhat similar in appearance to black shank. Sore-shin has not been studied extensively in Kentucky and

Figure 27. A tobacco plant infected with *Sclerotium bataticola*. The roots appear uninjured. The fungus seemed to have entered thru a decayed leaf. The decayed pith is peppered with just visible black sclerotia.

aside from its occasional appearance in tobacco fields, little is known about it. A single outbreak was studied which occurred in Calloway County in 1934. The disease was caused by the fungus *Sclerotium bataticola*. It occurred during a damp period when the temperature was over 100° F for several days. The stalks were decayed from the ground line upward. The pith was

a decayed mass in which numerous barely visible black masses or sclerotia were imbedded. The presence of the sclerotia distinguishes the disease from black shank. It is not likely to become a serious factor in tobacco production altho the fungus is a common soil inhabitant in Kentucky.

Black Shank. In 1935, black shank was found in a field of tobacco near Guthrie and in another field about 8 miles west of Elkton. The disease was present in both fields the year before. In one field it was estimated by the owner that between 500 and 1000 plants were destroyed in a small area. An outbreak of the disease was reported in Tennessee also. Nearly all the plants were destroyed in an area covering an acre or more. It is probable that the disease has been present in western Kentucky for several years.

The disease is caused by a soil-inhabiting fungus* which penetrates the roots or base of the plant and spreads up the stalk and down into the roots. The stalk is blackened as the fungus proceeds. Water-soaked concentric bands are evident on the blackened stalk. The pith is separated into discs as in lightning injury. As the fungus spreads it produces a toxin which causes rapid wilting of the entire plant.

The disease has proved very destructive in Florida and North Carolina, rendering infested soil entirely unfit for tobacco production until resistant varieties were available. An outbreak of the disease which occurred in North Carolina about 10 years ago has spread over an area 60 miles long and a few miles wide. It appears to have followed streams. One of the outbreaks in Kentucky was on the bank of a stream.

Prevention. Fields in which the disease occurs should be sown with grass as a means of destroying the fungus or at least as a means to prevent it being carried to other fields. It has been demonstrated that the fungus may be carried on wagon wheels or the feet of animals to other fields, then appears in these fields when they are cropped with tobacco. Resistant varieties must be developed if the disease becomes prevalent.

* *Phytophthora parasitica* var. *Nicotianae.*

Two of the Kentucky Experiment Station root-rot resistant varieties of dark tobacco tested in infested soil in North Carolina were found to be fairly resistant to black shank. This indicates that there should be little difficulty in developing resistant varieties of dark tobacco for Kentucky.

Stalk-Rot or Hollow Stalk. During wet seasons a rot of the pith of tobacco stalks is not uncommon. Infection is reported to occur thru wounds before the plant is topped or thru the

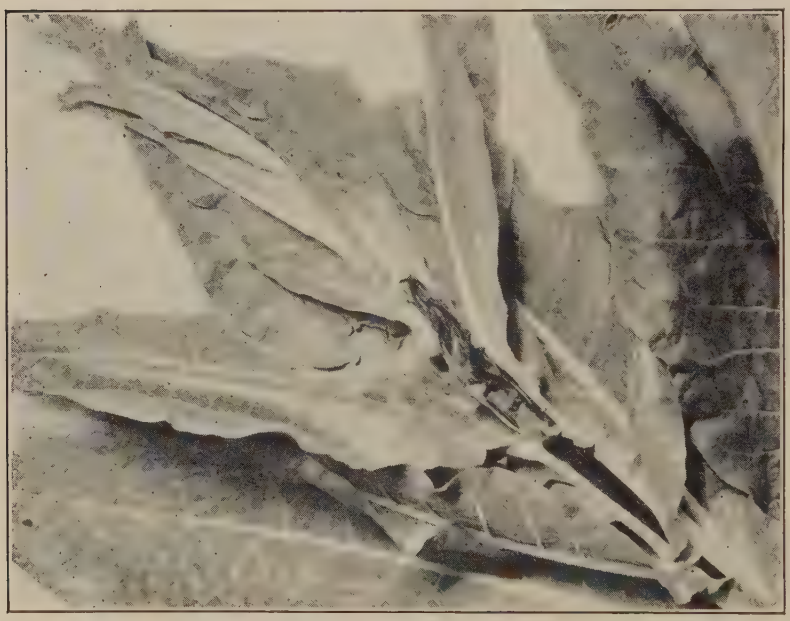

Figure 28. Stalk-Rot or Hollow Stalk produced by inoculation with bacteria from a plant affected by black-leg in the bed.

wound left by breaking out the top. Seed stalks sometimes become infected thru wounds made when the lower branches of the inflorescence are broken off. It is possible that the bacteria causing black-leg may be carried into the plant bed with seed from infected seed heads. The stalk disease spreads rapidly, and causes a soft-rot of the pith and stem tissue (figure 28). The disease is caused by the same organism which causes black-

leg of tobacco in the plant bed. No means of prevention is known and because of the comparative rarity of the disease, it would hardly seem necessary to take preventive measures again its possible appearance, even if such measures were known.

HOUSEBURN

Poor curing of the tobacco crop is the cause of immense losses to tobacco growers year after year. The injury to tobacco known as houseburn is probably the greatest single factor in this loss.

Houseburn is the result of the growth of fungi and bacteria on and in the dead leaves when they become moist during periods of high relative humidity. It does not occur during the yellowing period except in parts of the leaf which have been killed. The organisms are not active at low temperatures hence houseburn does not occur in cold weather. The ideal conditions for houseburn are a temperature between 60° and 100°F and relative humidity above 90 percent which checks the evaporation from the leaf and causes it to become soggy. Suckers left on the plant tend to induce houseburn in the leaves in contact with them.

In order to prevent houseburn several essential points in the curing of tobacco should be understood.* These are as follows:

1. Tobacco should be cut when it is properly ripened; that is, when there is an accumulation of food material in the leaves principally in the form of starch. The leaf is then a lighter green, and has a flecked appearance. Ripe tobacco leaves are brittle because of the accumulation of starch, and snap when folded between the fingers.

2. Curing is a life process during which the green coloring matter breaks down and the leaf becomes lemon yellow. The starch is used in the process and other contents of the leaf are changed. Curing and yellowing are accelerated by rather

* This discussion is largely condensed from the publications on curing tobacco by W. W. Garner of the Bureau of Plant Industry, Washington. For a more extensive discussion of tobacco curing see United States Department of Agriculture Farmers Bulletin 523.

rapid wilting and retarded when the leaf is turgid or full of water. Besides the loss of water in drying, the leaf loses about 12 to 20 percent of its weight from the use of starch, during the yellowing process. A further loss is caused by the passage of materials from the leaf into the stalk. The presence of suckers on the stalk during curing increases the loss of leaf weight in the attempt of the plant to keep the suckers alive. Drying and death of the plant are accelerated by splitting the stalk. It is therefore likely that splitting the stalk in harvesting tends to increase the weight of the leaf, as compared with spearing. The death of portions of the leaf from bruising, frost, too rapid drying, or other cause prevents them from curing, and produces green patches in the cured leaves.

3. Following yellowing the leaf quickly dies, altho the stalk remains alive for a longer time. Death of the lower leaves naturally occurs first and death of the edges of the leaves precedes that of the remainder. When yellowing is completed and the tissues are dying the remainder of the curing process is primarily one of slowly drying the leaf.

4. Browning or reddening which follows the death of the leaf is caused by oxidation of substances in the leaf. It proceeds best at a relatively high humidity and more rapidly at higher temperature. Each time the tobacco becomes damp or "comes in high case", the depth of color increases. The chief danger in air curing is that this process will go too far because of excess moisture, causing the leaf to cure too dark.

5. Leaf activity nearly ceases at 40°F, but becomes more active as the temperature is raised. At 125°F the cells of the leaf are rapidly killed, while at 115°F longer exposures kill the leaf. The best temperatures for the first stage of curing or the yellowing process are between 60° and 100°F. A barn to which artificial heat is not applied rarely becomes too hot but it may readily become too cold for proper curing.

6. Relative humidity or the percentage of saturation of the air at a given temperature is an important factor in curing. During yellowing a relative humidity of 85 percent is desirable.

If it goes to 90 percent or above, microorganisms may develop, on dead portions of the leaves, and houseburn may occur. If it goes much lower than 80 percent the tobacco may dry too rapidly. At ordinary temperatures, a rise of 20°F changes the relative humidity of a saturated atmosphere to about 50 percent. In other words, the water-holding capacity of the air is doubled by a rise of 20°F. A barn full of tobacco at a moderate temperature may become wet if a rainy period sets in with rising temperature. This is because vapor from the saturated atmosphere condenses on the cooler leaves.

7. Heated air rises and passes out of the ventilators at the top of the house, carrying off the excess moisture. Air of high humidity is lighter than drier air and passes out of the top ventilators. In cold weather the curing processes stop and if drying continues the leaf simply dries out.

With these facts in mind the principles involved in preventing houseburn and too dark a color in the cured leaf are more readily understood. The tobacco should be wilted as much as is practicable before being put into the house. It should then be kept at a temperature between 60° and 100°F, and at a relative humidity of about 85 percent. The relative humidity may be determined by the use of a wet and dry bulb thermometer together with the necessary tables. Such a pair of thermometers, properly mounted, is called an hygrometer. In dry weather the humidity may be maintained by keeping the barn tightly closed during the day and open at night. The barn of course, should be capable of being closed tight. In wet weather when the air is saturated, humidity can be regulated only by heat and proper ventilation. In Burley and air-cured dark tobacco barns this may be done with coke fires, either on the floor (with gas coke) or in specially constructed burners. In the fire-cured dark-tobacco barns it is commonly done with wood fires. When fires are used the upper ventilators should be opened sufficiently to carry off the moisture-laden air and the lower ventilators opened sufficiently to allow the cooler air to enter. It should be remembered that heating the air increases its water-holding capacity. When yellowing has been completed

and the leaves are dead the relative humidity should be decreased first to about 80 percent and later to 65 to 70 percent and maintained at that point until the stalks are dry. At this point curing is complete. After the tobacco is cured it should be bulked down, as soon as it can be brought sufficiently into case for handling, and stripped and graded as soon as possible. It should be remembered that each time tobacco becomes damp, either during the second period of curing or after curing, the color is darkened and there is danger of houseburn.

In curing fire-cured tobacco the same principles apply. The tobacco should hang in the barn for three or four days to bring about yellowing. This may be hastened about the fourth day by slow fires which raise the temperature to about 85° to 95° F.

If a temperature of about 85°F with a relative humidity of about 85 percent is maintained during the remainder of the curing period, the cure will be more satisfactory than if the temperature is gradually raised to 125°F or higher. Slow, very smoky fires maintain the necessary temperature and impart the desired smoky aroma to the tobacco. When the cure is completed, slow fires should be built during periods of high humidity.

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